

# A Ka-Band (26 GHz) Circularly Polarized 2x2 Microstrip Patch Sub-Array with Compact Feed

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**Abstract**— A Ka-Band (26 GHz) 2x2 sub-array with square-shaped microstrip patch antenna elements having two truncated corners for circular polarization (CP) is presented. In addition, the layout for a new compact microstrip feed network for the sub-array is also presented. The compact feed network offers a footprint size reduction of near 60% over traditional sub-array at 26 GHz. Experimental data indicates that a truncation amount  $a = 0.741$  mm for an isolated patch element results in a return loss ( $S_{11}$ ) of -35 dB at 26.3 GHz. Furthermore, the measured  $S_{11}$  for the proof-of-concept sub-array with the above elements is better than -10.0 dB at 27.7 GHz. However, the impedance match and the operating frequency can be fine-tuned to 26 GHz by adjusting the feed network dimensions. Lastly, good agreement is observed between the measured and simulated  $S_{11}$  for the sub-array for both right hand and left hand CP. The goal of this effort is utilize the above sub-array as a building block for a larger NxN element array, which would serve as a feed for a reflector antenna for satellite communications.

**Index Terms**—Microstrip Patch Antenna Sub-Array, Ka-Band, Circular Polarization

## I. INTRODUCTION

Satellite communication requires robust, high gain, small-size, light weight, circularly polarized (CP) data links that can reliably operate for long periods of time in harsh conditions. The durability and simplicity of microstrip antenna arrays make them an excellent choice as a feed for a high gain reflector antenna as part of a satellite communication system.

This paper describes the design, fabrication, and testing/operation of a 26 GHz, CP, 2x2 planar sub-array with corner truncated patch elements. This work includes the design of a single corner truncated patch element (truncation amount =  $a$ ) and a new sub-array feed network architecture. This sub-array is more simple than other high frequency sub-arrays [1] and smaller than arrays with traditional feed [2].

Each section of this paper (II - IV) presents a new contribution on Ka-band CP patch antenna. In section II important trade-offs between corner truncation and axial ratio (AR) are shown. Section III contains new discontinuity compensation methods, and section IV introduces a new Ka-band feed network.

## II. SINGLE PATCH ELEMENT

A corner truncated patch element with single input

microstrip feed is designed/fabricated on ½ oz. copper clad, 10 mil thick, Rogers 5880 ( $\epsilon_r = 2.2$ ) board using well-known design equations [3]. When the corners are truncated, the antenna radiates with circular polarization. Fig 1 shows the geometry of the antenna.

A truncation amount of  $a = 0.741$  mm gave an  $S_{11}$  of -35 dB at 26.3 GHz. Reducing the truncation reduces the  $S_{11}$  but results in a larger AR bandwidth. For example, for  $a = 0.741$  mm the antenna has two regions with a 3dB AR bandwidth: 1st centered at 25.25 GHz (1.9% bandwidth) and 2nd centered at 27.85 GHz (5.4%). Reducing the truncation to  $a = 0.600$  mm

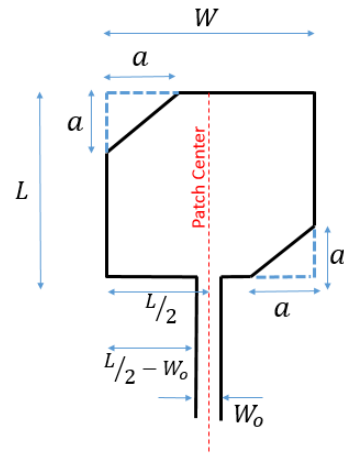


Fig 1. The geometry of a corner truncated patch antenna.  $W_0 = 0.741$  mm, 50  $\Omega$  feed line is used here. Side length,  $L = W = 3.749$  mm, is calculated using equations from [3] The truncation amount,  $a$ , determines the  $S_{11}$ .

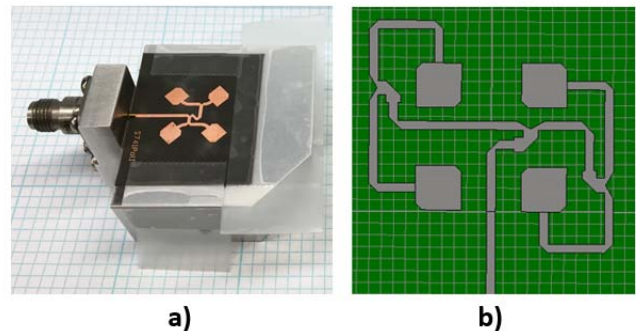


Fig. 2. Compact and traditional 2x2 sub-array layout. Fig. 2a shows the fabricated compact array and test fixture on 0.1" grid paper. The sub-array has a footprint of 196 mm<sup>2</sup>. Fig. 2b shows a traditional sub-array on 1mm grid. The traditional sub-array has a footprint of 484 mm<sup>2</sup>.

shifts the two 3dB AR regions to 25.3 GHz (2.4%) and 26.75 GHz (4.1%), respectively.

### III. ANTENNA FEED NETWORK

Sequential rotation (SR) of adjacent patch elements in an array has been shown to improve input impedance bandwidth, polarization purity, and radiation pattern [4]. This SR technique has also been shown to produce strong CP when a 2x2 sub-array is fabricated from linearly polarized elements. The sequential phasing (SP) of the CP patch elements in an array has also been shown to improve its overall CP performance. The SP of an array is created by advancing the phase of each successive CP patch element by  $90^\circ$  when compared to the adjacent element [4].

The layout for a traditional 2x2 SP sub-array operating at 26 GHz is shown in Fig. 2 (b). Rotating the elements and adapting the feed system results in a more compact sub-array as shown in Fig. 2 (a). The compact feed network utilizes microstrip lines with uniform width for the quarter wave transformers, which reduce excess line lengths and simultaneously provide good impedance match at the tee-junctions. This design represents a significant size reduction,

which is essential for building larger arrays, especially at Ka-band frequencies. This layout is based on an adaptation of a novel design and demonstration at 2.5 GHz reported in [5].

Due to the complex electromagnetic environment of the feed network, the quarter wave transformer line lengths can be adjusted to shift the sub-array resonant frequency and to improve AR. Additional work has been performed to demonstrate a novel rectangular tee-junction compensation technique that can be used to improve phase separation as well as equalize the power division at the junction.

### IV. 2X2 SUB-ARRAY CHARACTERIZATION

The  $S_{11}$  of 2x2 sub-arrays with corner truncated patch elements designed using analytical techniques is characterized with a network analyzer and the test fixture shown in Fig 2(a). The measured and simulated  $S_{11}$  for the two opposite sense of CP are compared in (a) & (b), respectively.

The 2x2 sub-arrays shows good resonance centered just below 28 GHz. Further optimization of the quarter wave transformers in the feed system is required to shift the resonance to 26 GHz. Further studies will examine the AR of the sub-array and its relationship to the feed network geometry and the amount of corner truncation,  $a$ .

Both sense of CP show similar resonance characteristics, however, a stronger resonance below 28 GHz with less spurious radiation in the 24-27 GHz band is observed for the sub-array in Fig. 3(b). Both the simulated and measured data support this observation.

### V. CONCLUSION

A 2x2 sub-array with a compact feed is designed and tested in this paper. A single patch element with  $a = 0.741$  mm operates at 26.3 GHz with a  $S_{11}$  of -35 dB. The measured and simulated sub-array results show strong agreement, with the best performance slightly below 28 GHz. The new feed network layout represents a 60% decrease in footprint area.

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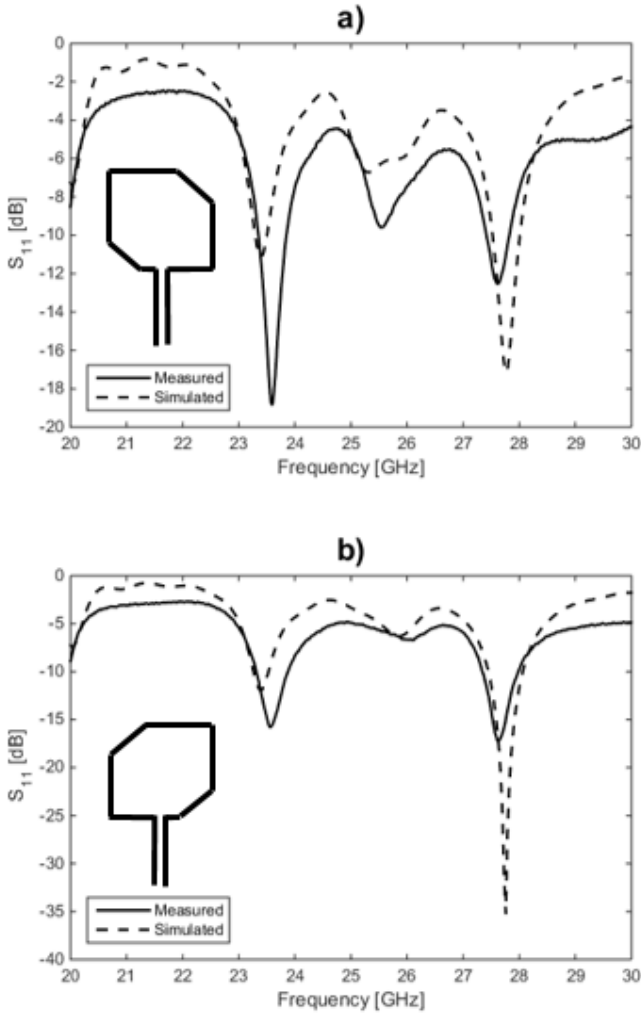


Fig. 3. A comparison between measured and simulated  $S_{11}$  results for the 2x2 sub-array with truncation amount,  $a = 0.741$  mm. Truncation geometry for elements in the array is shown for both sense of CP polarizations.